# Tropospheric humidity observations from AIRS and applications to climate and climate modeling

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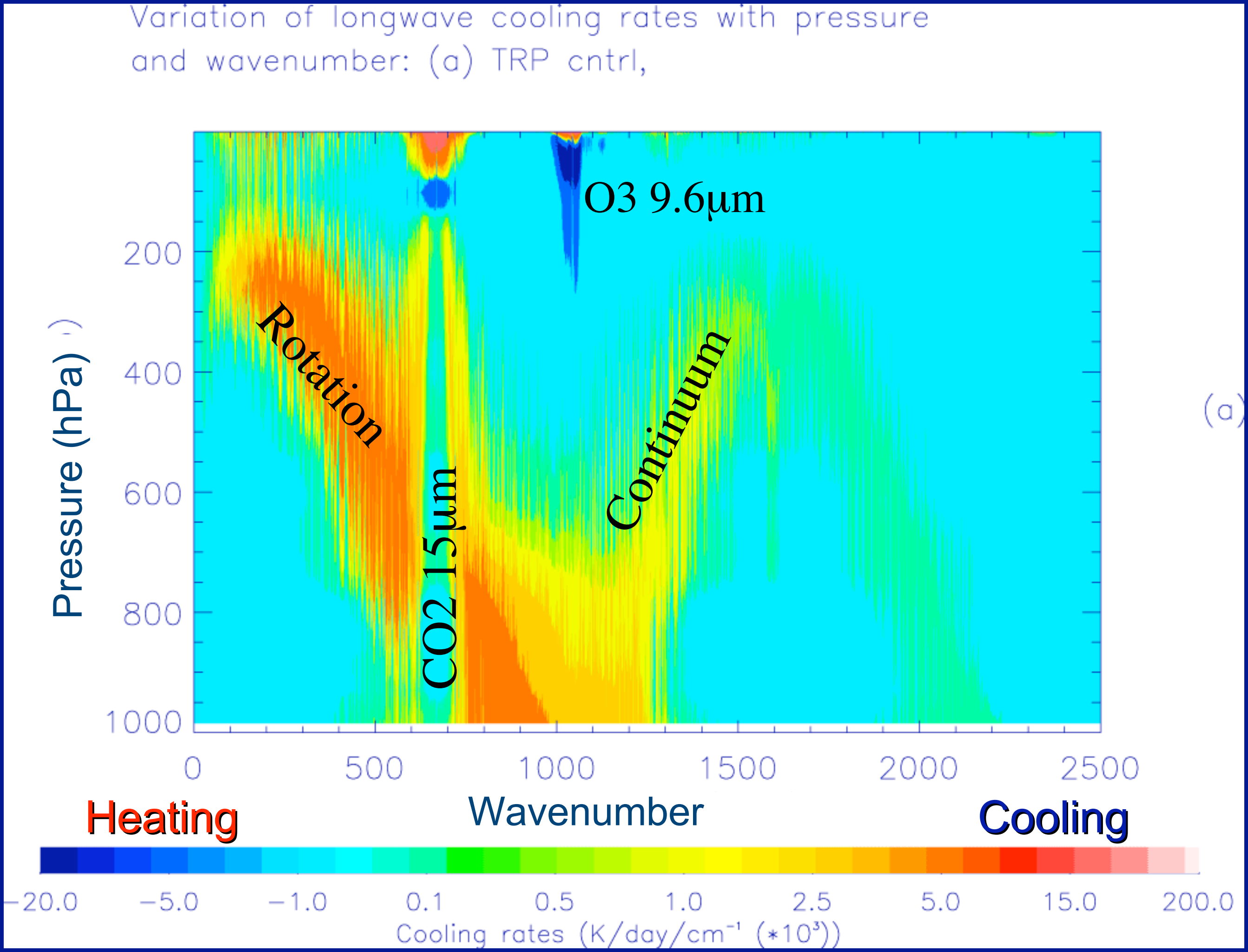
# "Water, water everywhere and not a drop to Drink"

Coleridge, *Rhyme of the Ancient Mariner*

- Motivation
- AIRS RH product, mean RH
- Simulating $H_2O$ in NCAR CAM3
- Observed Supersaturation
- Observed and simulated Climate Feedbacks

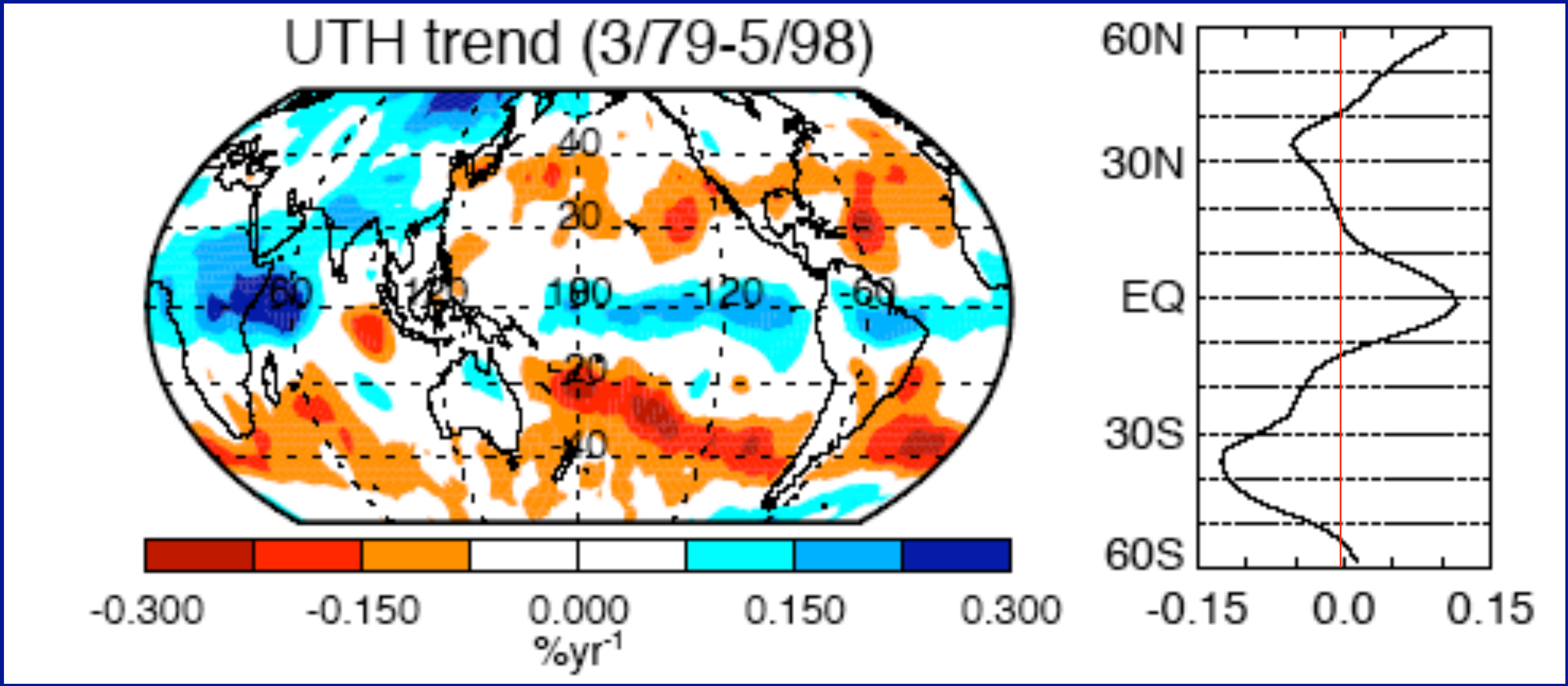
# $H_2O$ dominates Longwave




Brindley & Harries 1998 (SPARC 2000)

# Long Term UTH trends

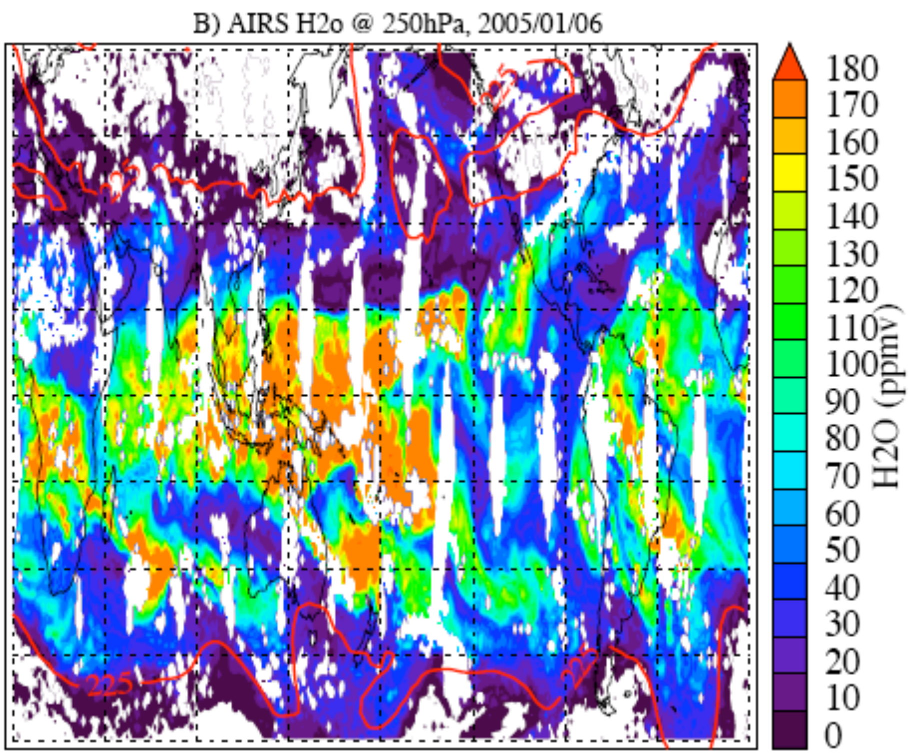
HIRS/TOVS trends

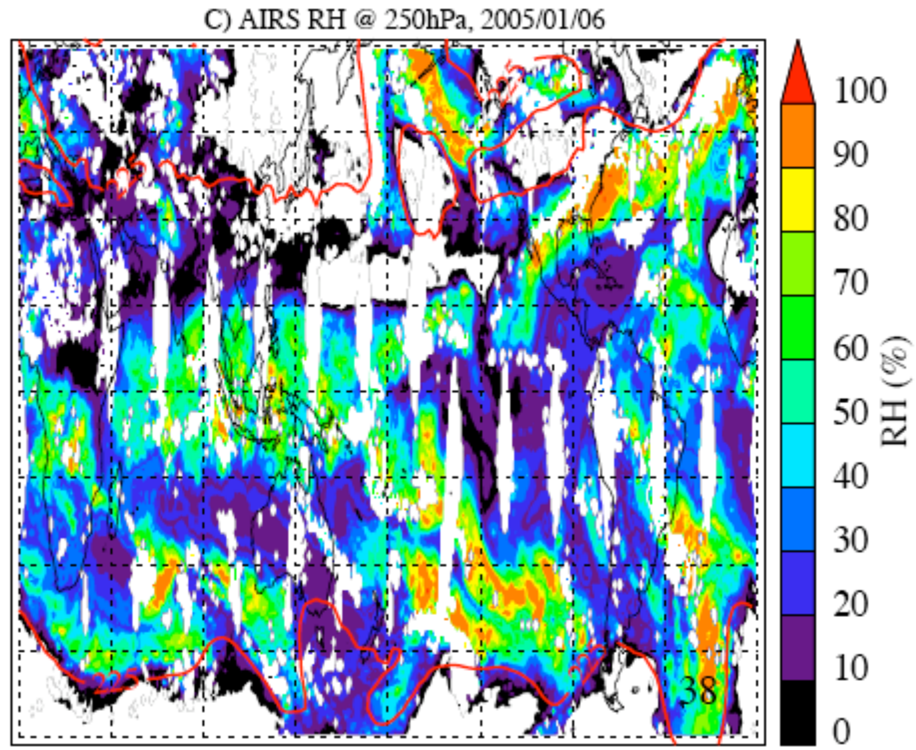



Bates & Jackson 2001, GRL

# AIRS Humidity Jan 6, 2005

Specific $[H_2O]$ | Relative

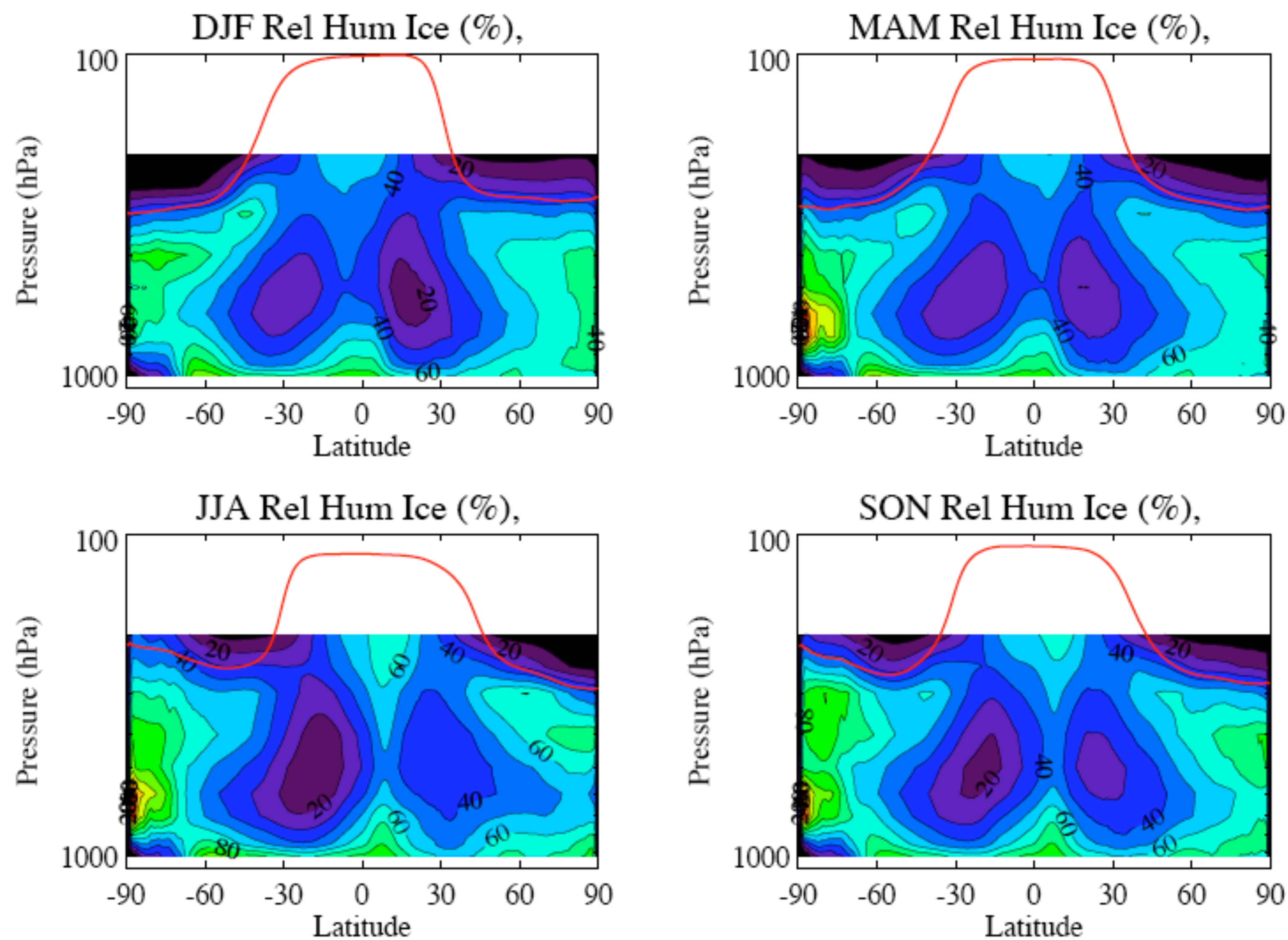


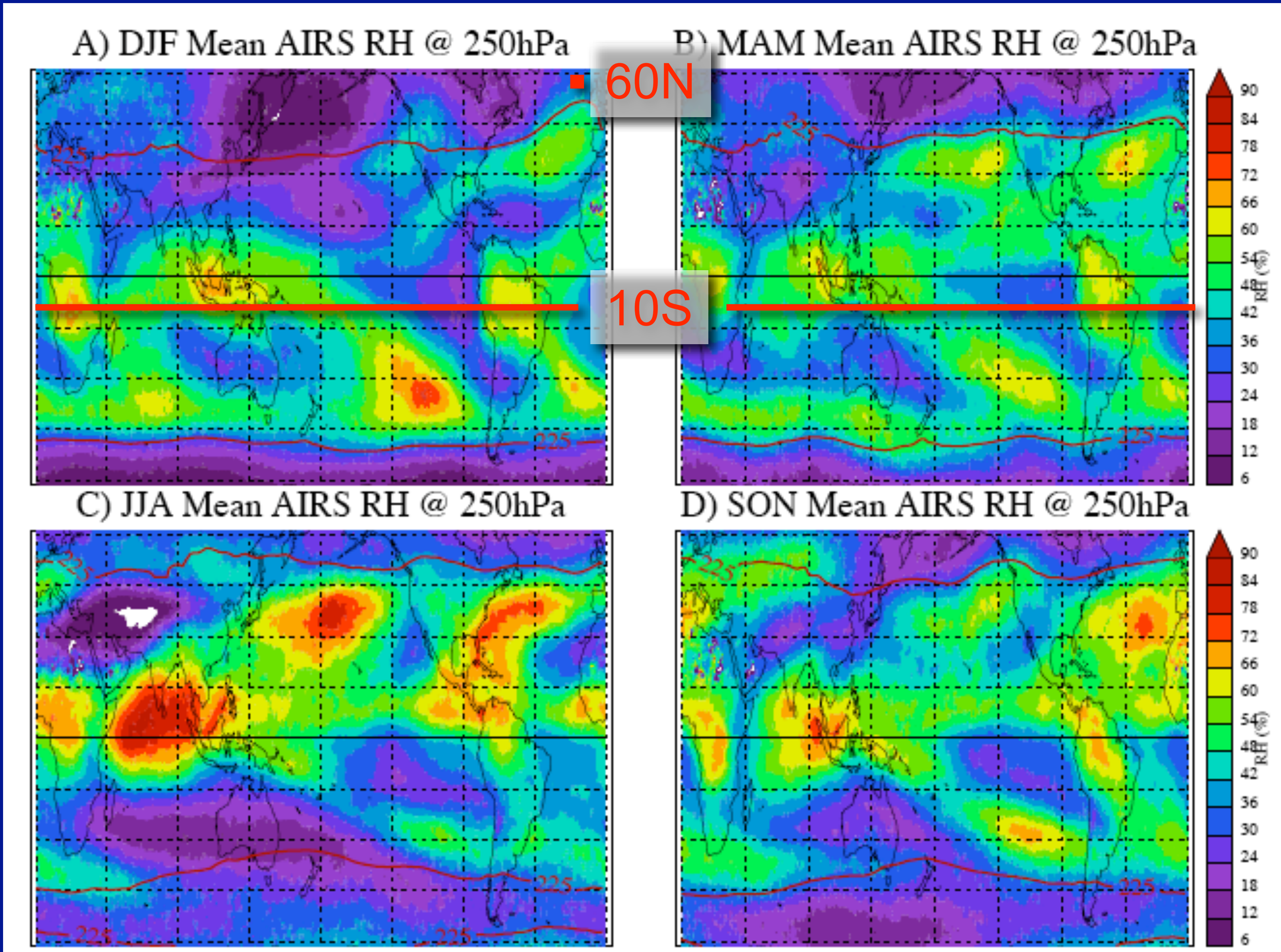

RH created from L2 retrievals (each profile):

$$RH(x,y,z)=H_2O(x,y,z) / \int q_s(T(x,y,z_0),T(x,y,z_1))\, dz$$

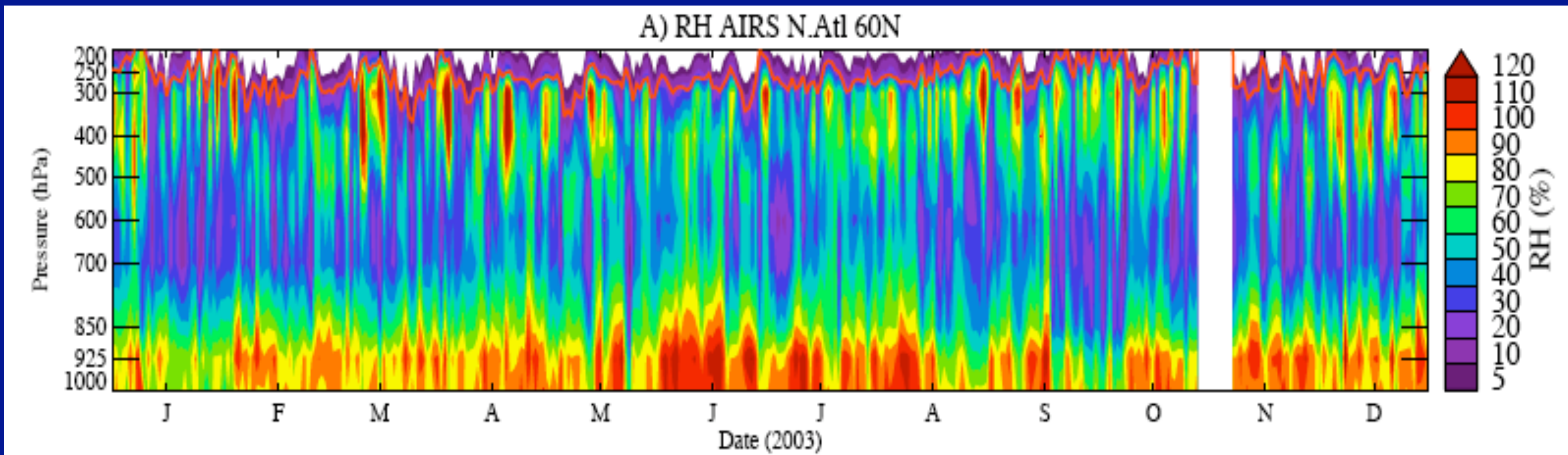
# Seasonal Zonal Mean (AIRS)



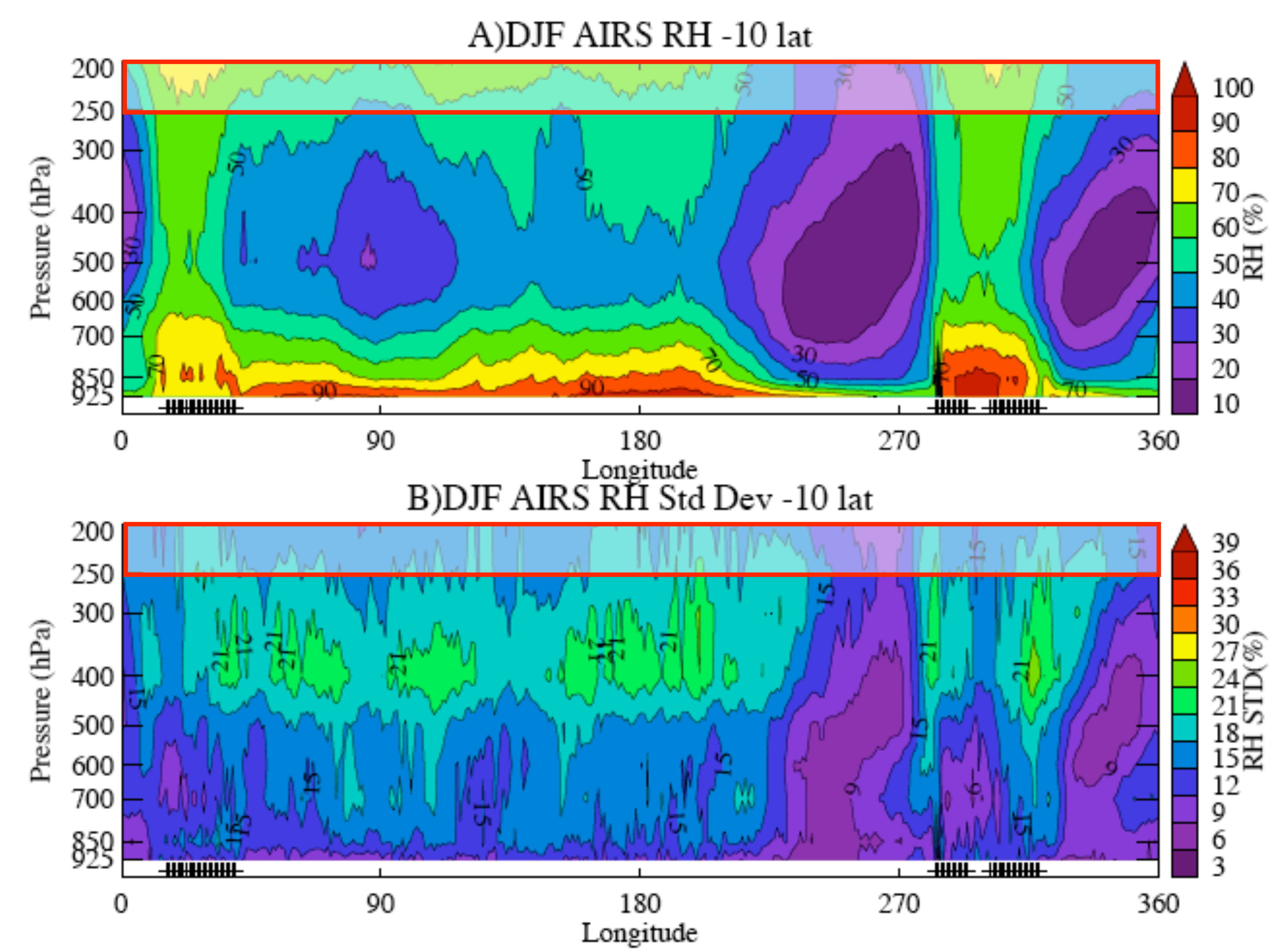
# Seasonal Mean 250mb RH



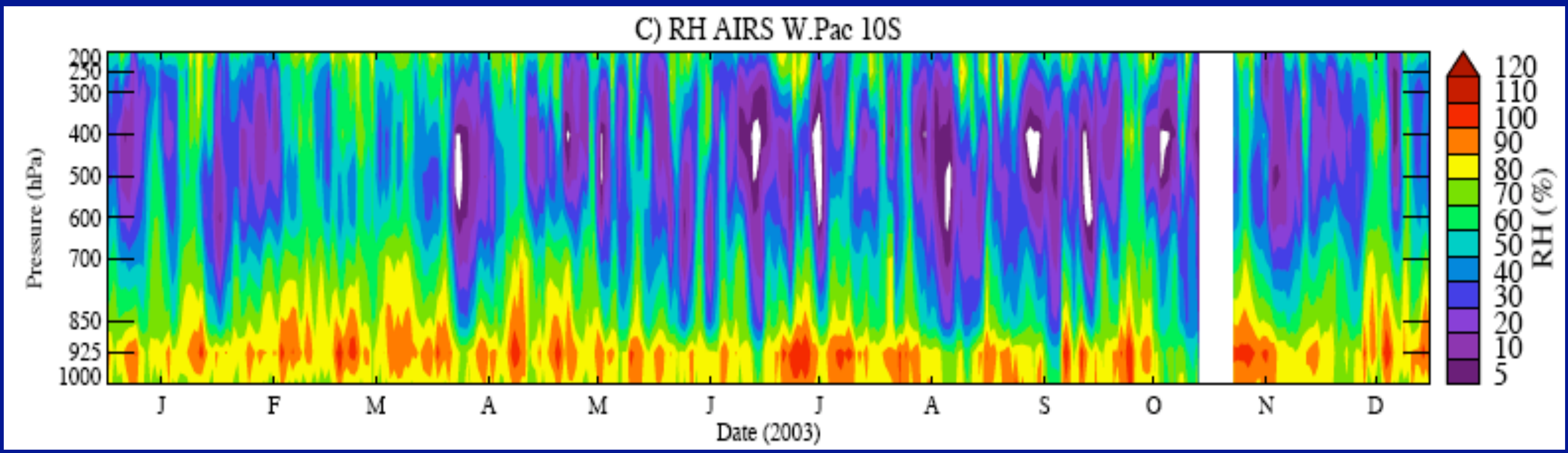
# Mid-Lat Variations: one point



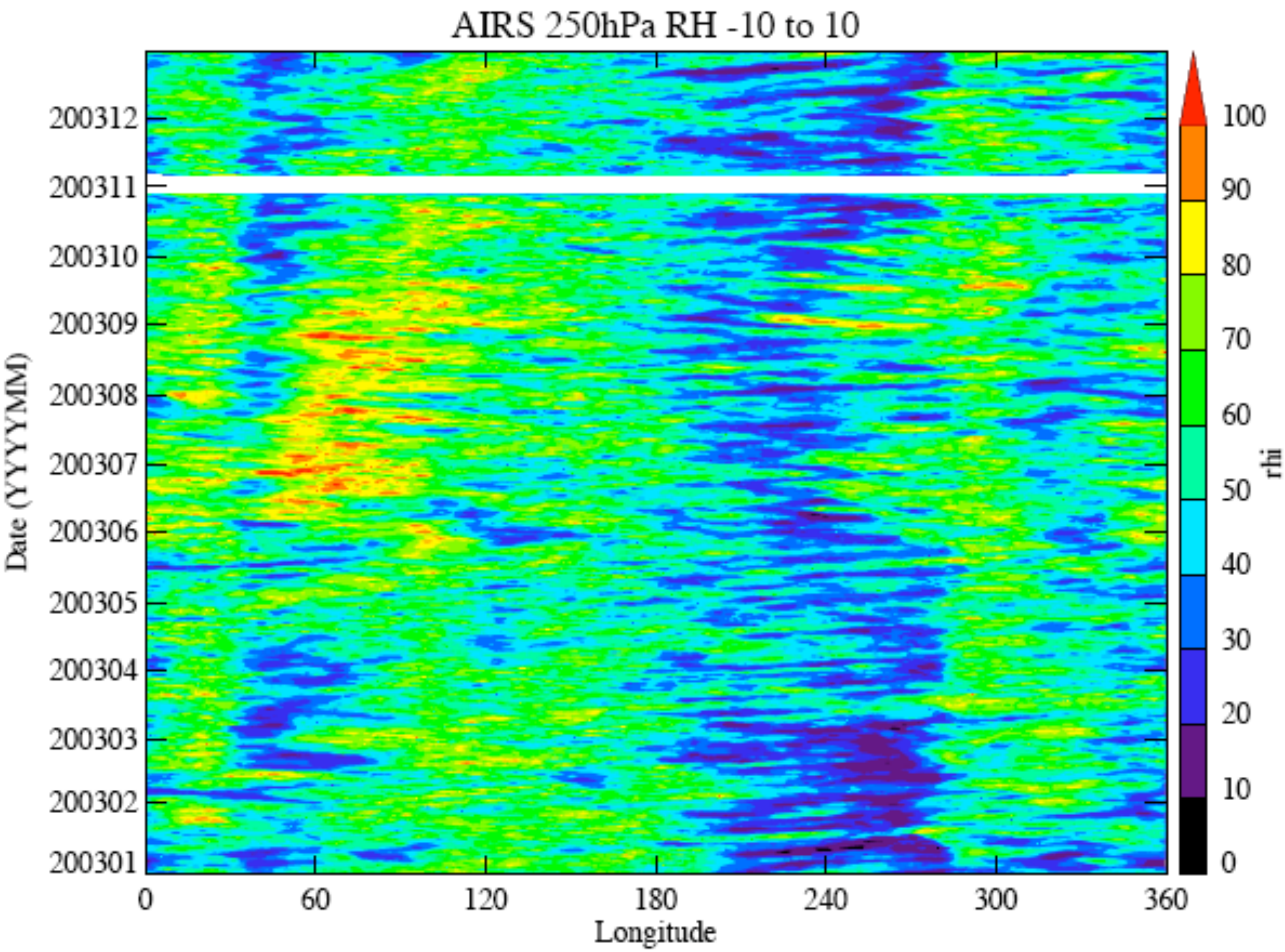
# Vertical Structure: Tropical Variability



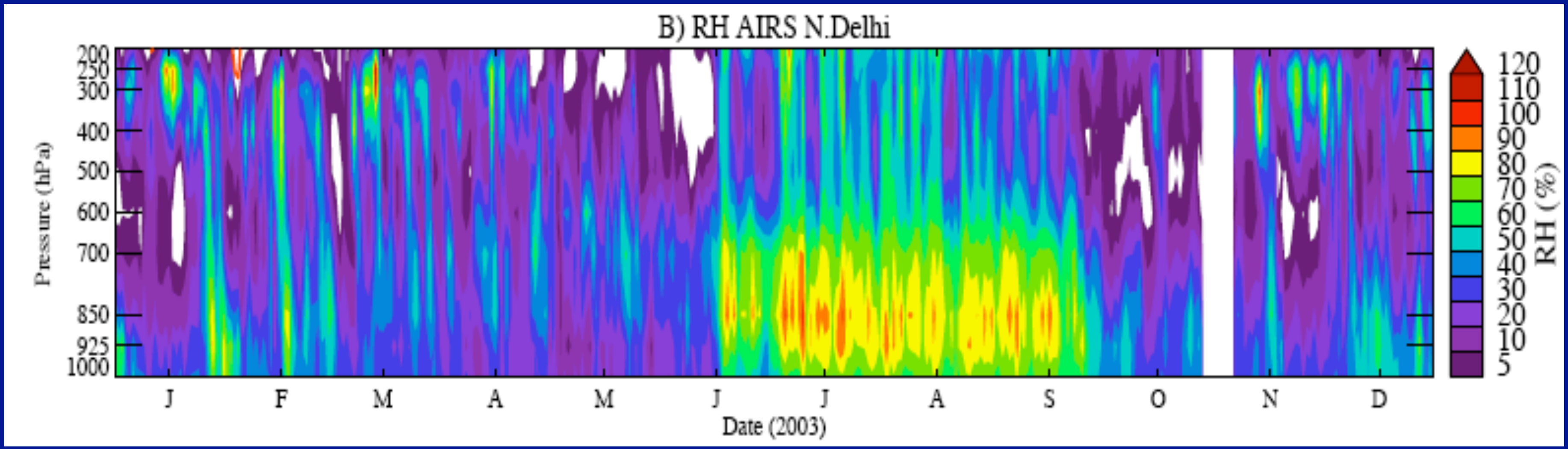
# Tropical Variations: one point



# Tropical UT/LS variations



# Subtropical Variations: New Delhi



# $H_2O$ in Climate models

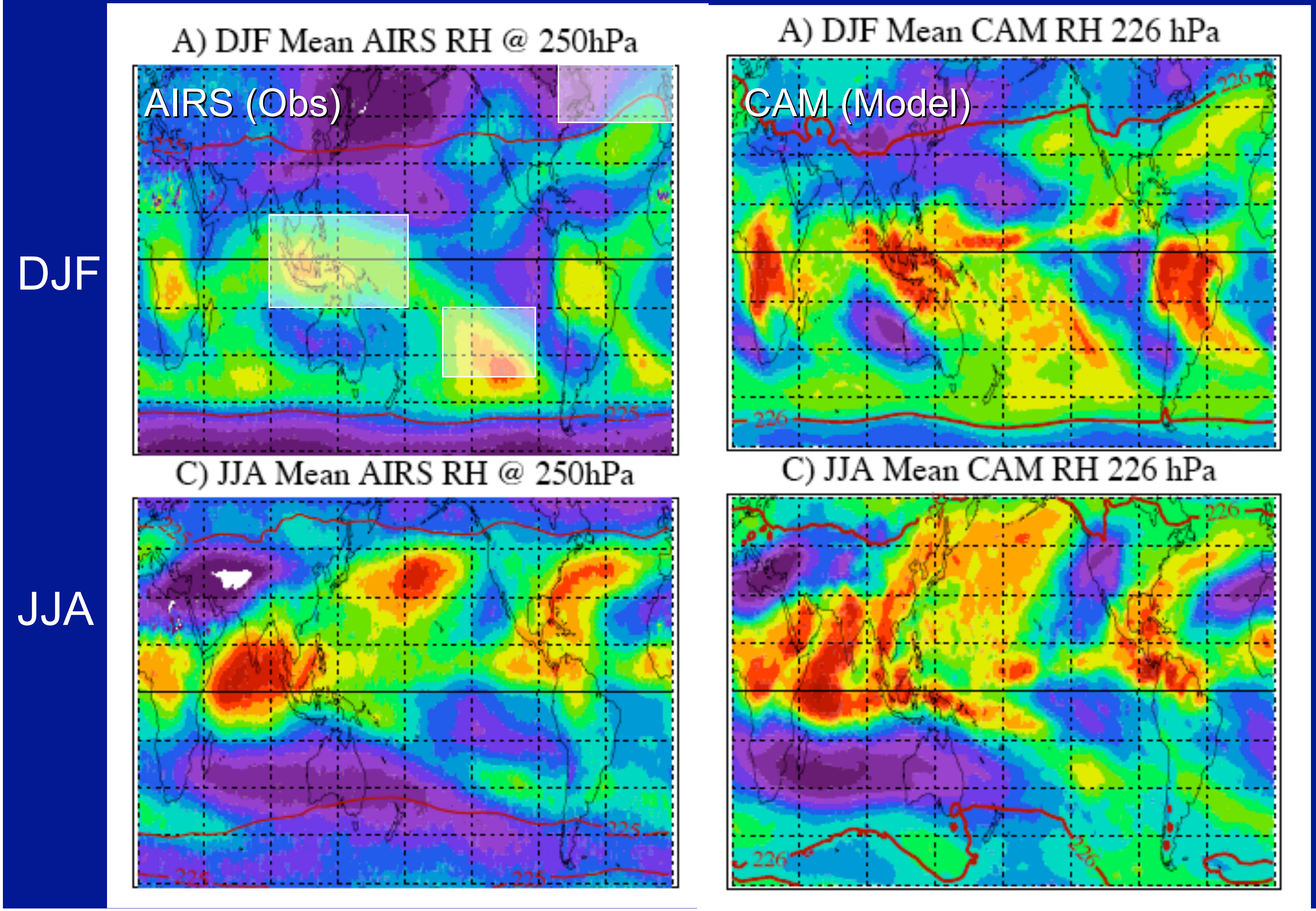
General Circulation Models (GCMs):

- Conserve mass and energy, RH < 100%
- Bulk condensation processes
  - Convection, Stratiform, Advection
- Subgrid ‘parameterizations’
  - Cloud fractions
  - Distributions of clouds, liquid
  - Bin or Moment microphysics
  - Nucleation of particles, aerosol interactions

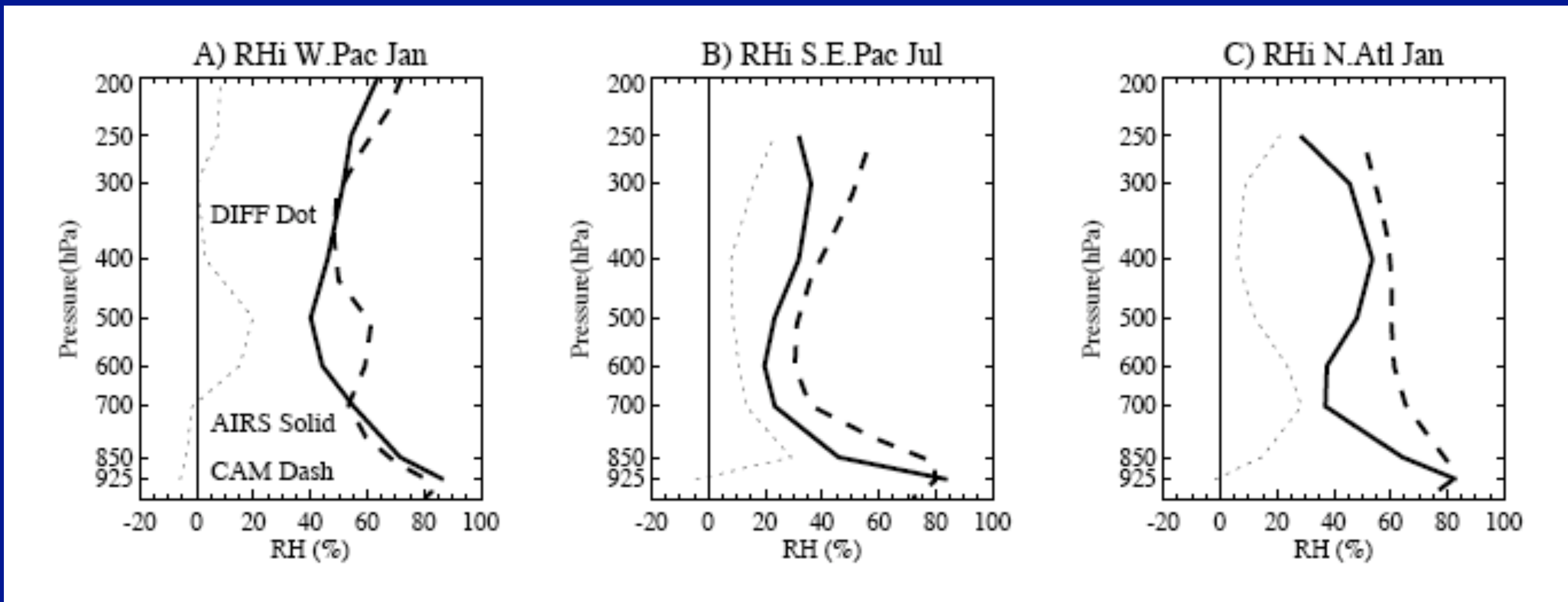
# Model v. Observations

- Mean $H_2O$ seasonal
- Standard Deviations
- Impacts on Radiation Balance/Heating
- Seasonal Cycle
  - ‘Tape recorder’
  - Isentropic transport
- Interannual variations: ENSO
- Trends: long term, recent change

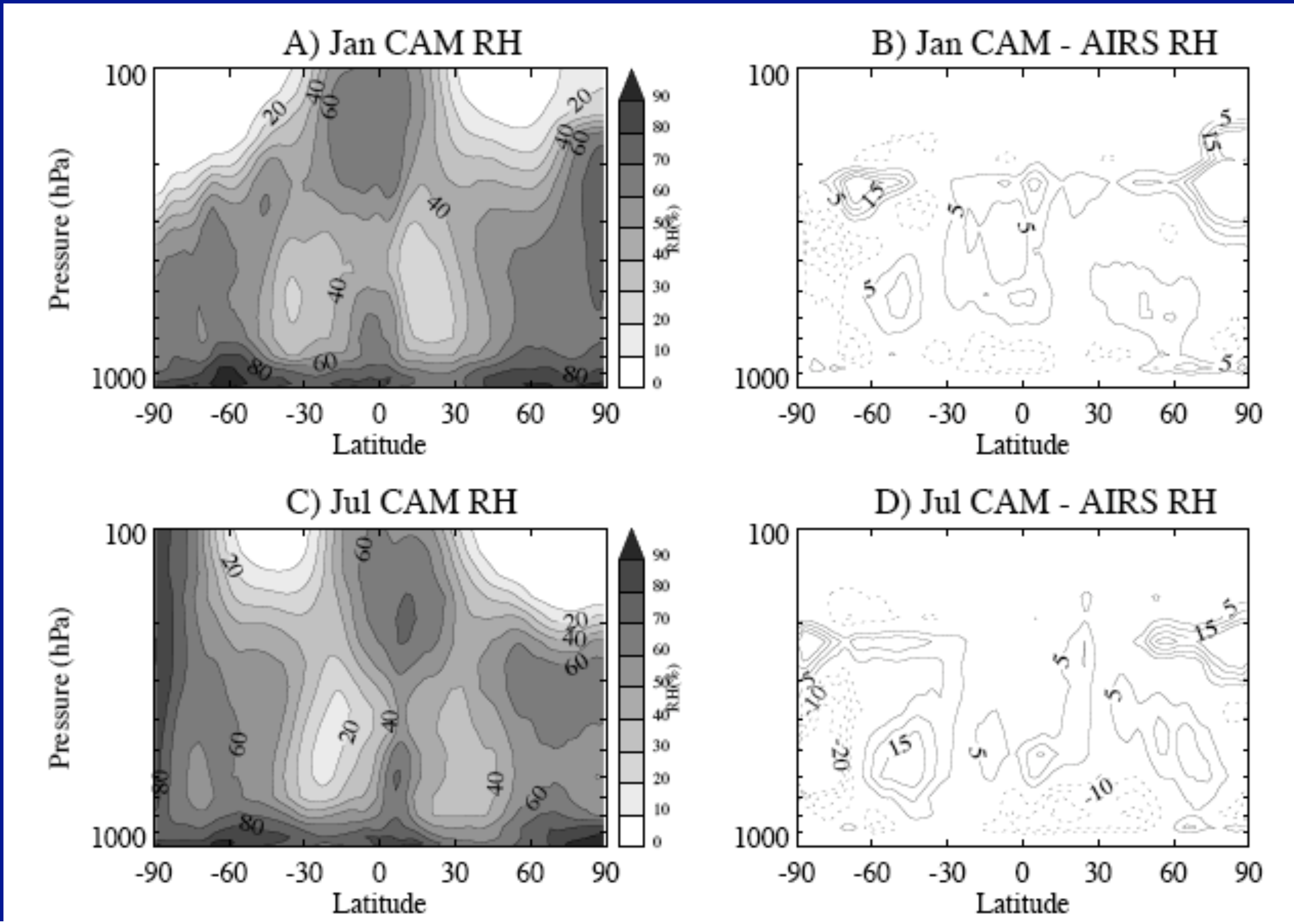
# Seasonal Comparison: 250mb



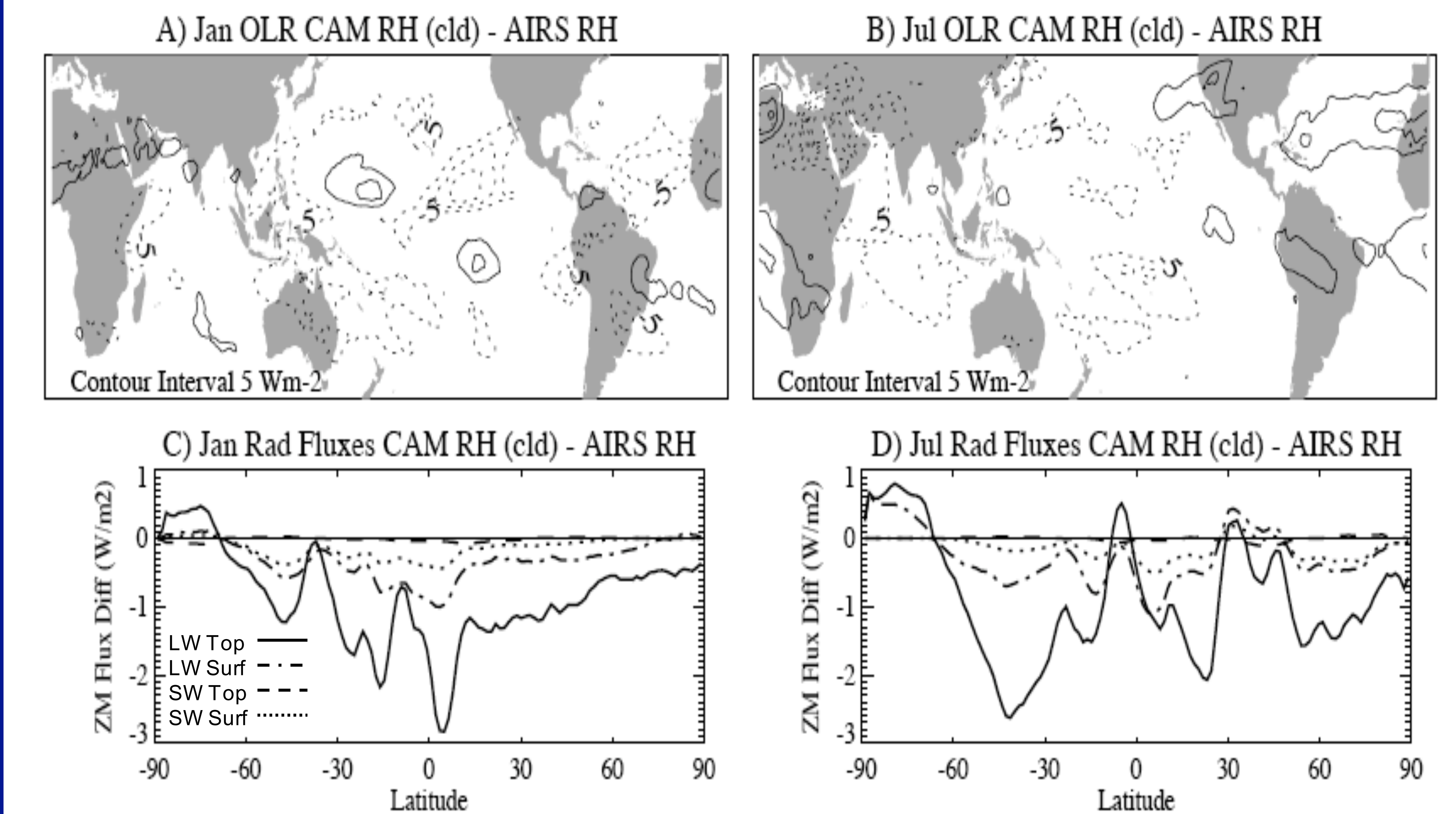
# AIRS v. CAM3: Profiles



# Zonal Mean CAM RH & Diff



# Impact on Radiative Fluxes



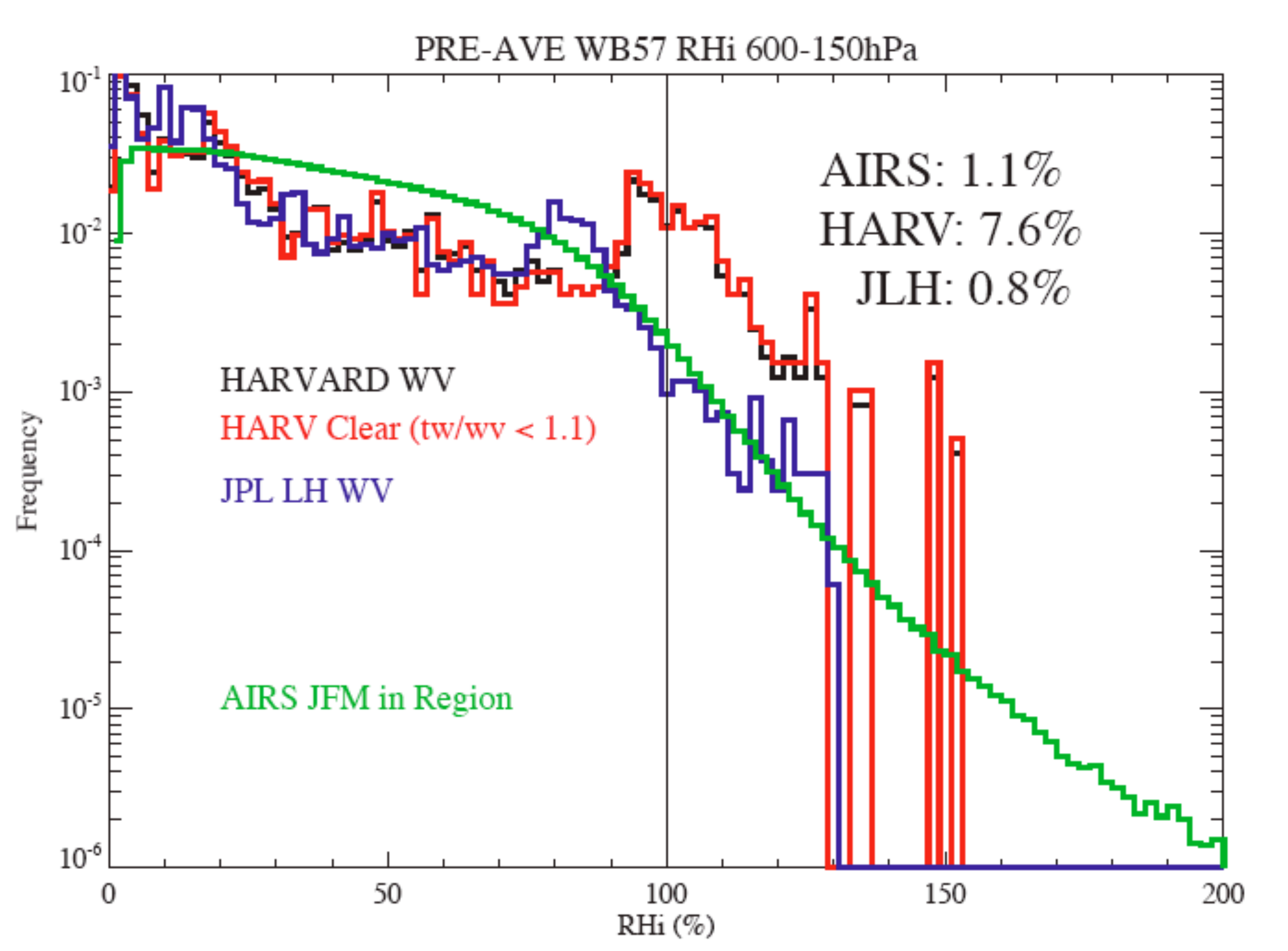
# Applications: Supersaturation

- Ice doesn't condense at 100% RHi
- Why?
  - RHi $\neq$ RHw (diff vapor pressures)
  - Ice doesn't form on its own: usually due to homogeneous/heterogeneous freezing
- Observations show potentially large RHi
  - Important for cloud formation, indirect effects of particles on radiative balance, stratospheric water vapor

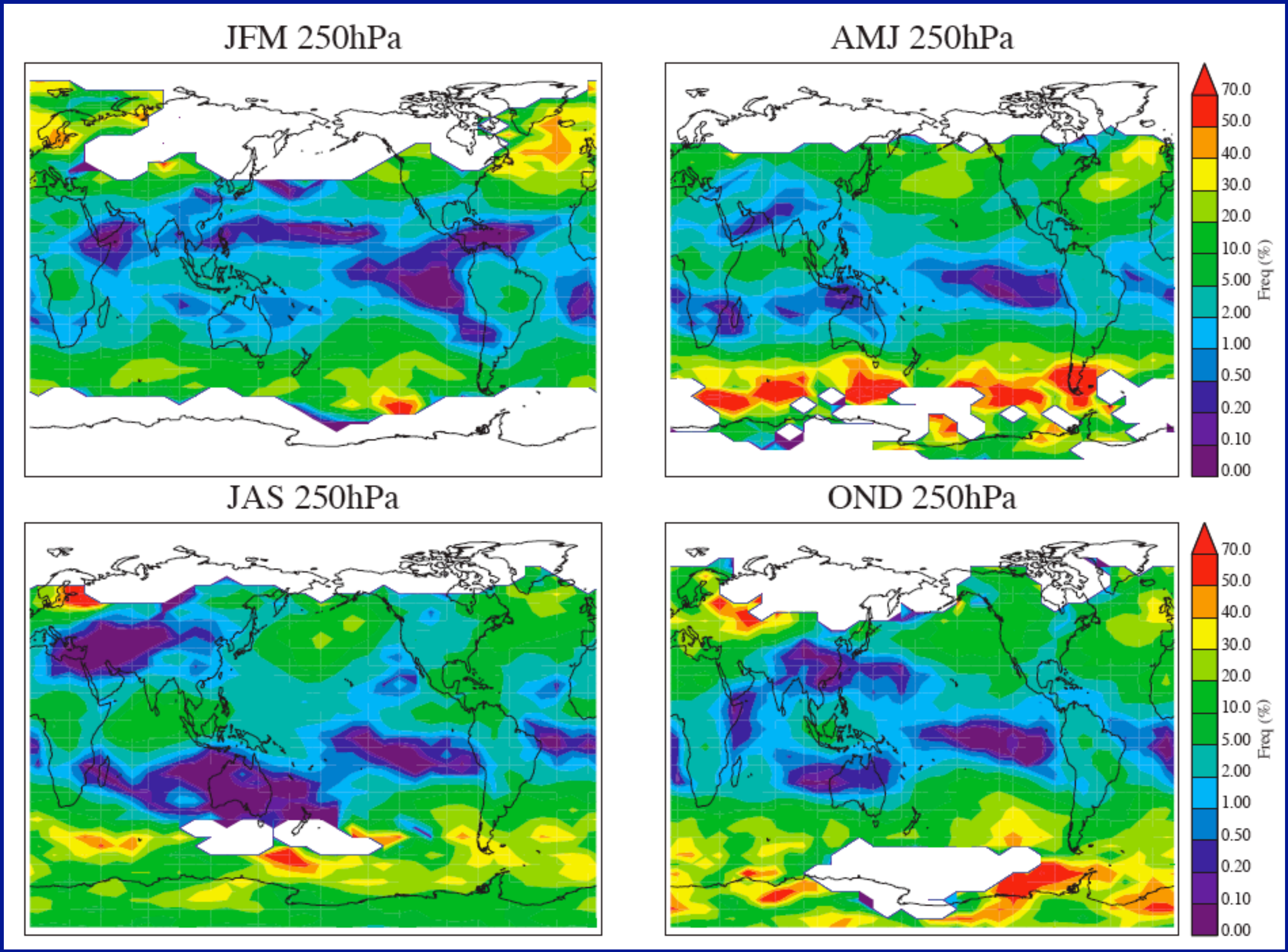
# Supersaturation: Tropics

Supersaturation (RH > 100%) seen in AIRS data

Validation against in situ data indicates some is ‘real’ (some is spurious)



# Supersaturation Frequency



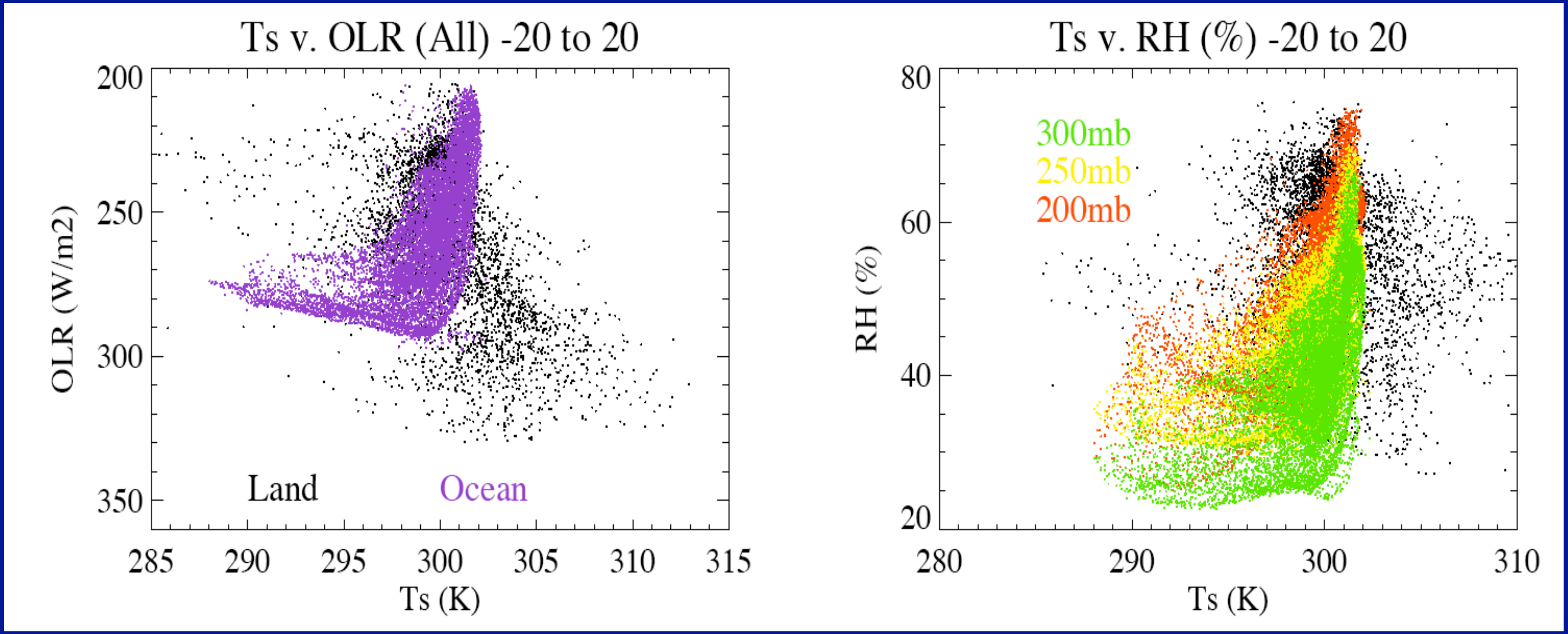
# Applications: Climate 'Feedbacks'

- How does the atmosphere respond to forcings?
  - UTH positive feedbacks
  - Lapse Rate, negative feedbacks (θe)
- Observations as an analogue for climate change
  - Relationships between Ts, OLR, Radiation
  - Note: AIRS OLR not good, need to use CERES
  - Temporal and spatial scaling? Test daily-> annual
- Compare Model and Observations

What's new: coverage, vertical resolution

**WARNING:** Work in progress

# $T_s$ v. OLR, RH (annual)




For $T_s$ > ~297K, get rapid increase in upper level RH & decrease in OLR (convection/clouds)

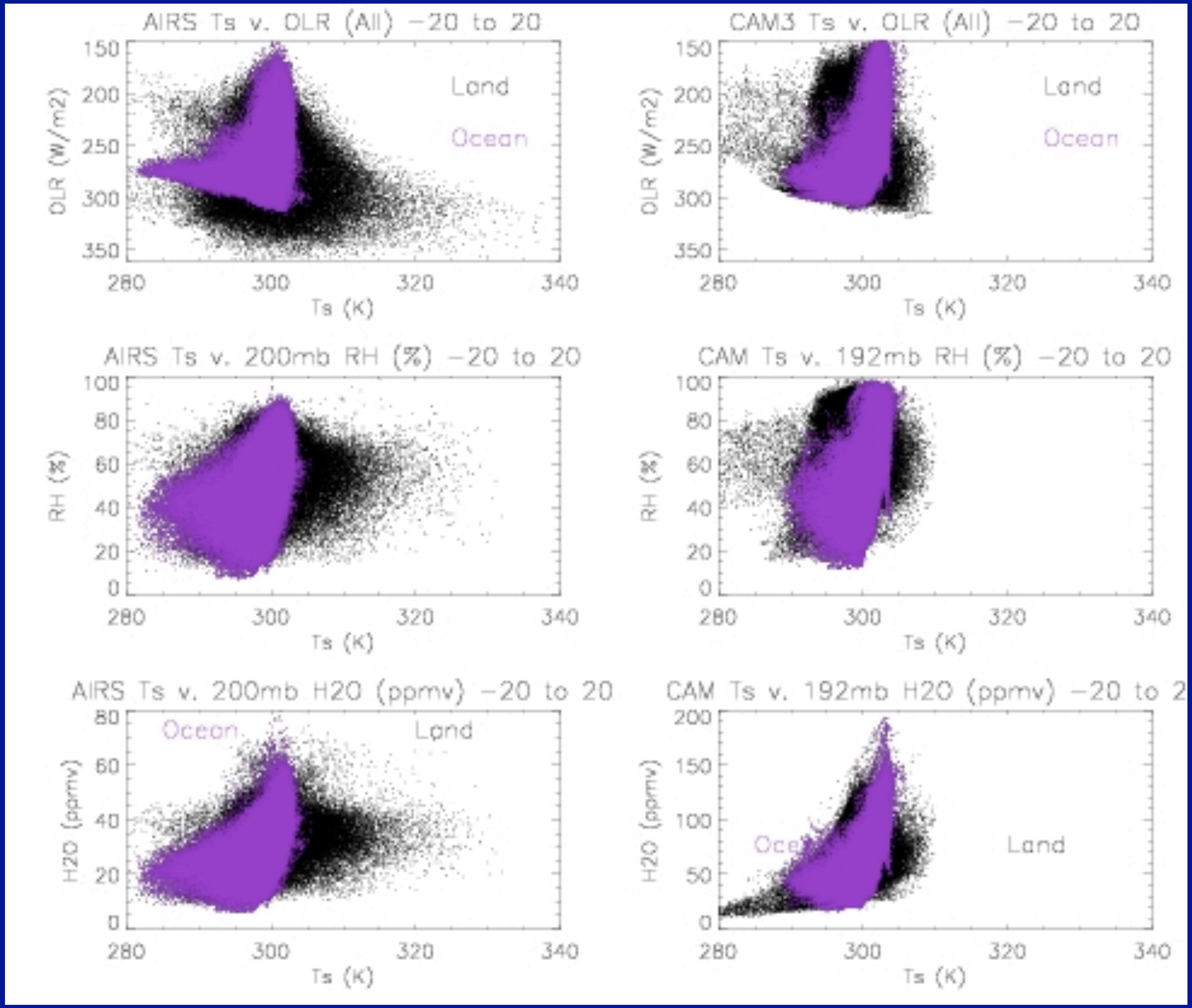
# Ts v. OLR, RH (monthly)

Observations | Model

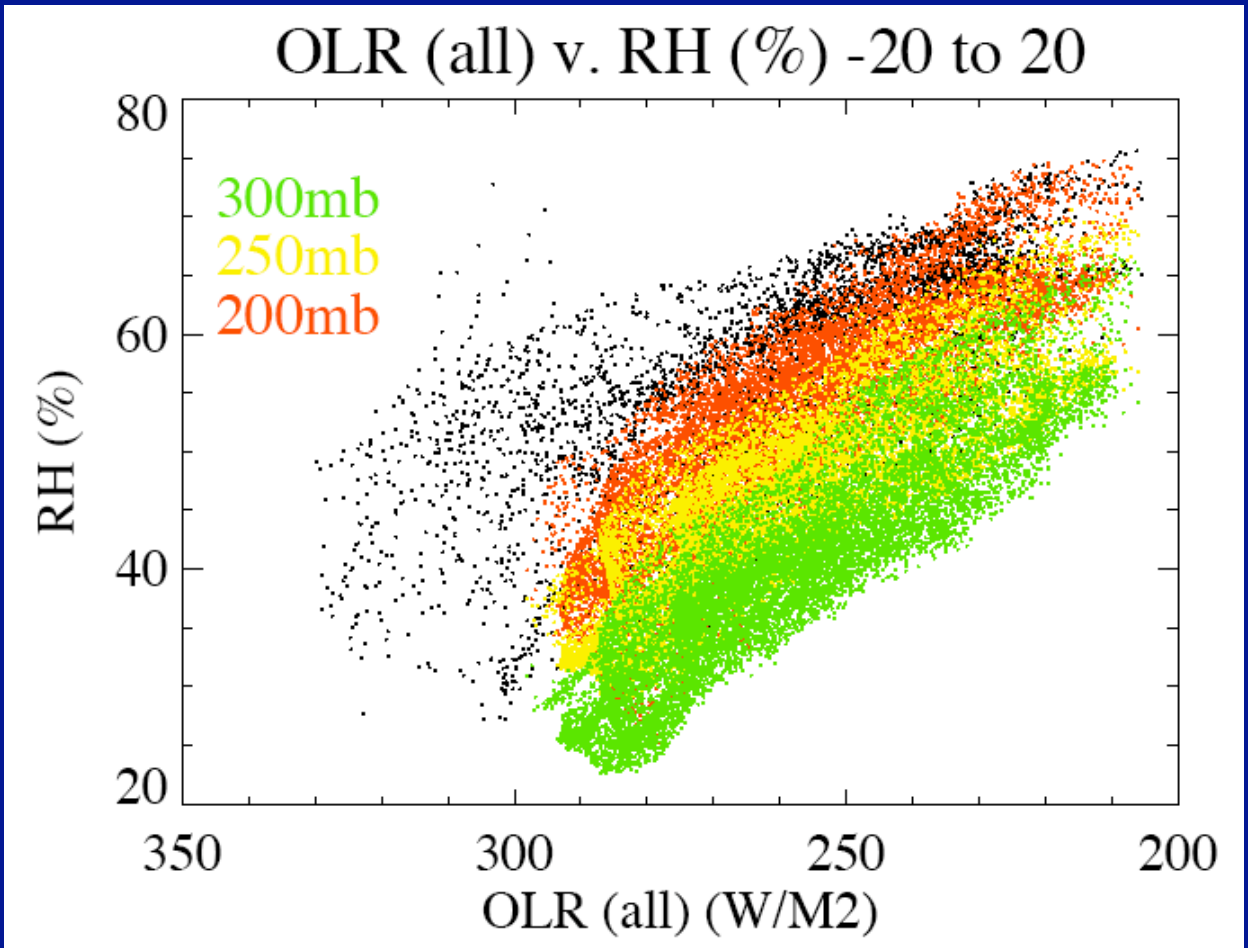
OLR

RH

$H_2O$
(specific humidity)



# OLR v. RH (annual)



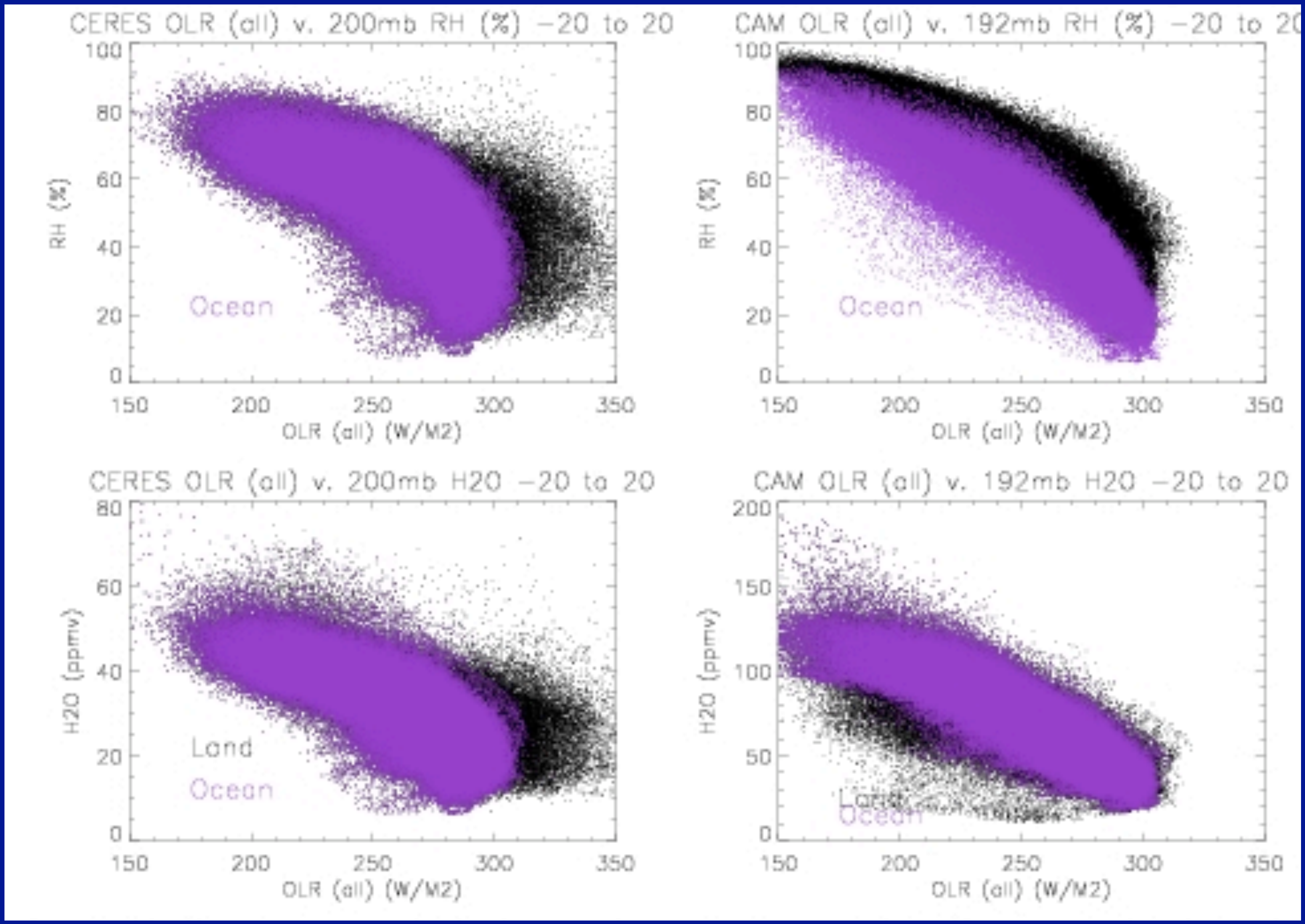

More clouds = More water (RH)

# Convection (OLR) v. RH

Observations | Model

Relative Humidity

Specific Humidity ($H_2O$)



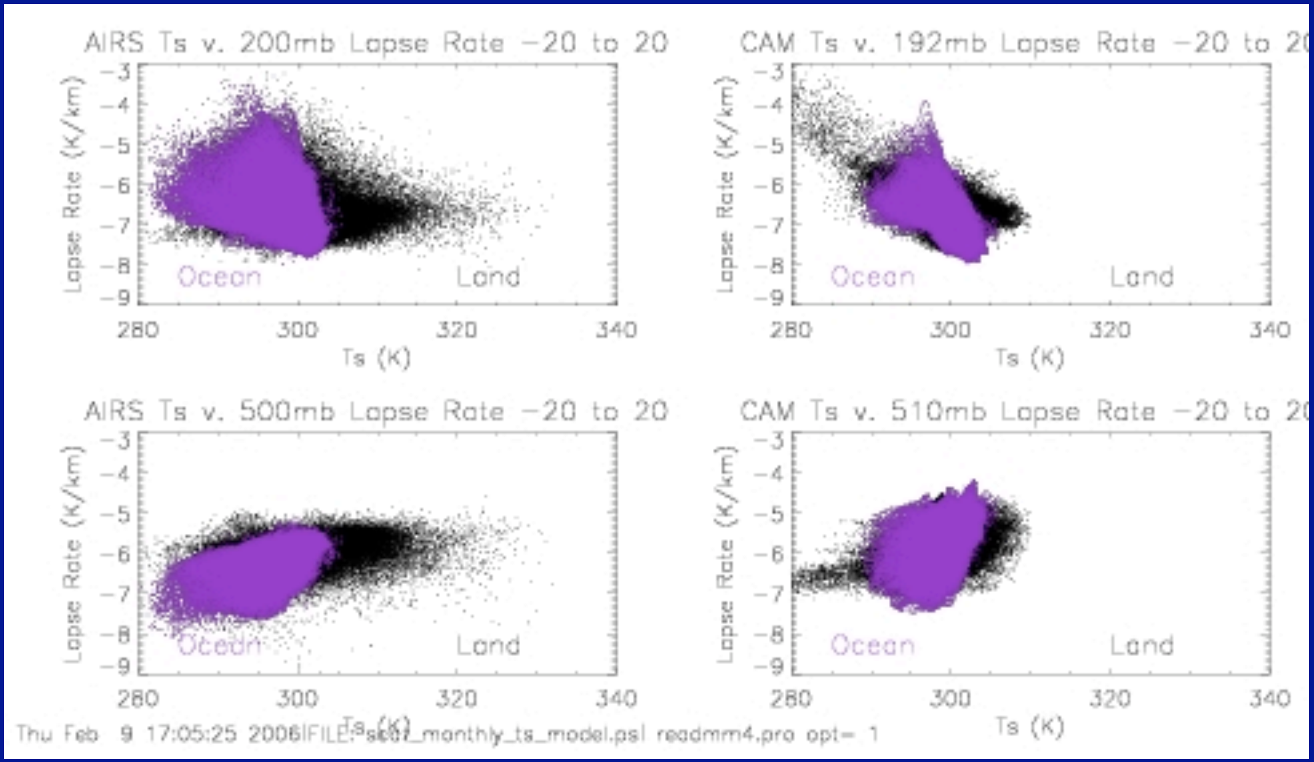

More clouds (lower OLR) = More water (RH)

# Lapse Rates (v. OLR, Ts)

Observations Model

UT (200mb)

LT (500mb)




Lapse rate (dT/dz) follows moist adiabat:

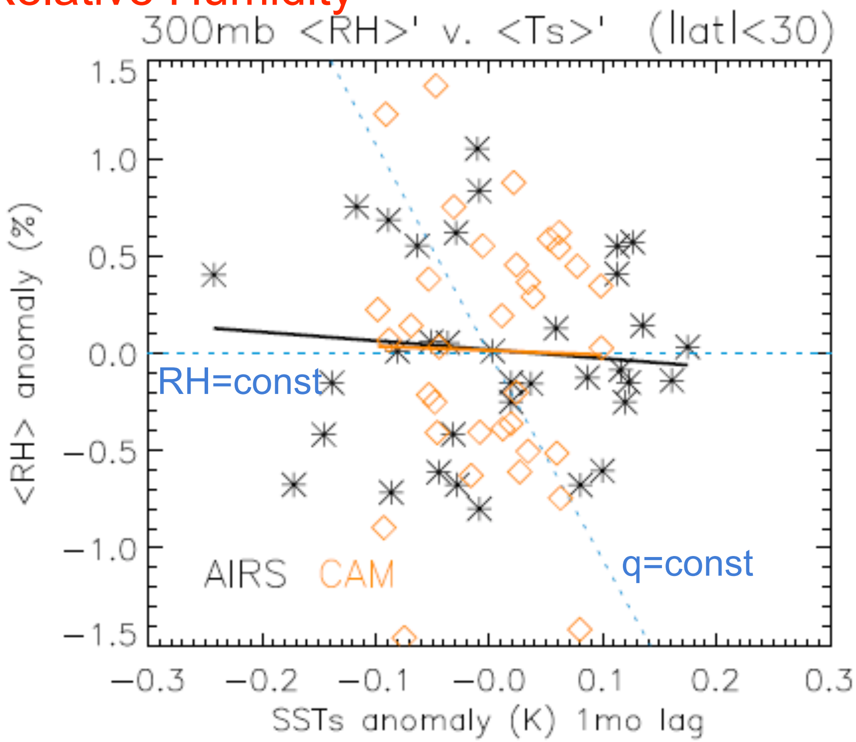
Warmer moist adiabat has larger dT/dz at upper levels,

But smaller dT/dz at lower levels (negative feedback)

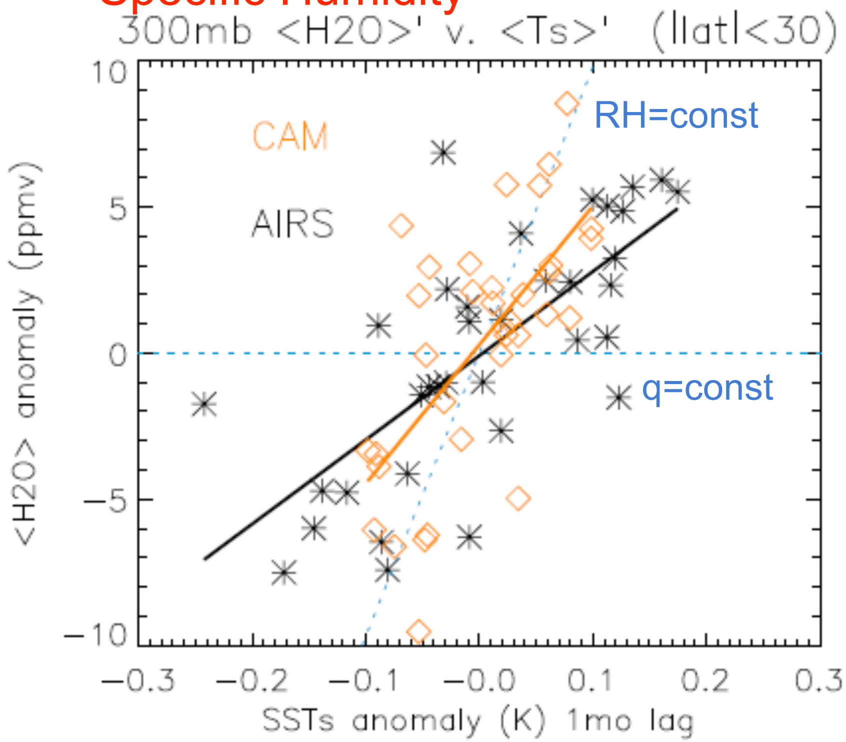
# ΔSST v. ΔUTH (monthly)

Observed UTH increases with SST, but less than RH=const

Relative Humidity




Specific Humidity

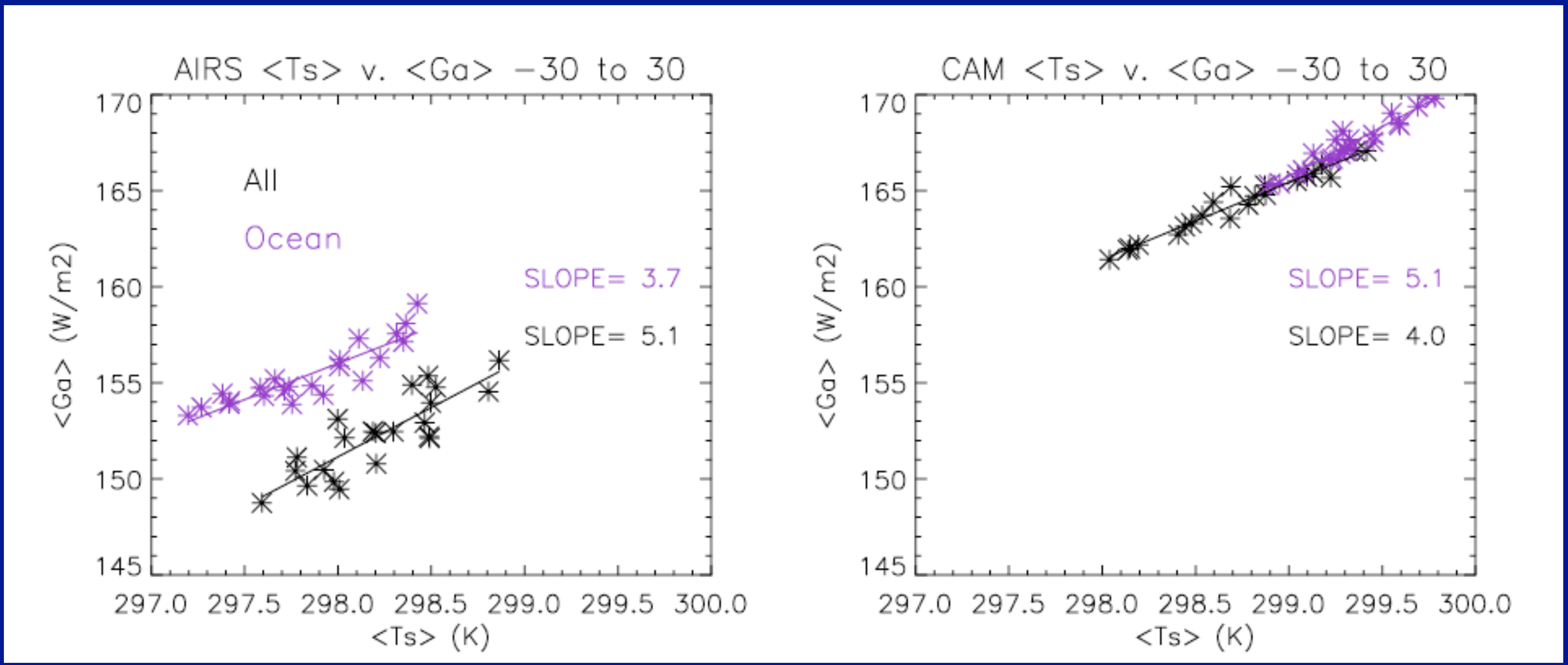



Consistent with: Minschwaner & Dessler, JOC 2004 (UARS/MLS, 215mb H2O)

# Greenhouse Parameter (GHP)

Atmospheric Trapping $G_a = \sigma T_s^4$ - OLR

Observations | Model




Differences in SST (model/obs), but slopes are similar.
Slope ($Wm^{-2}K^{-1}$) a gross measure of greenhouse effect

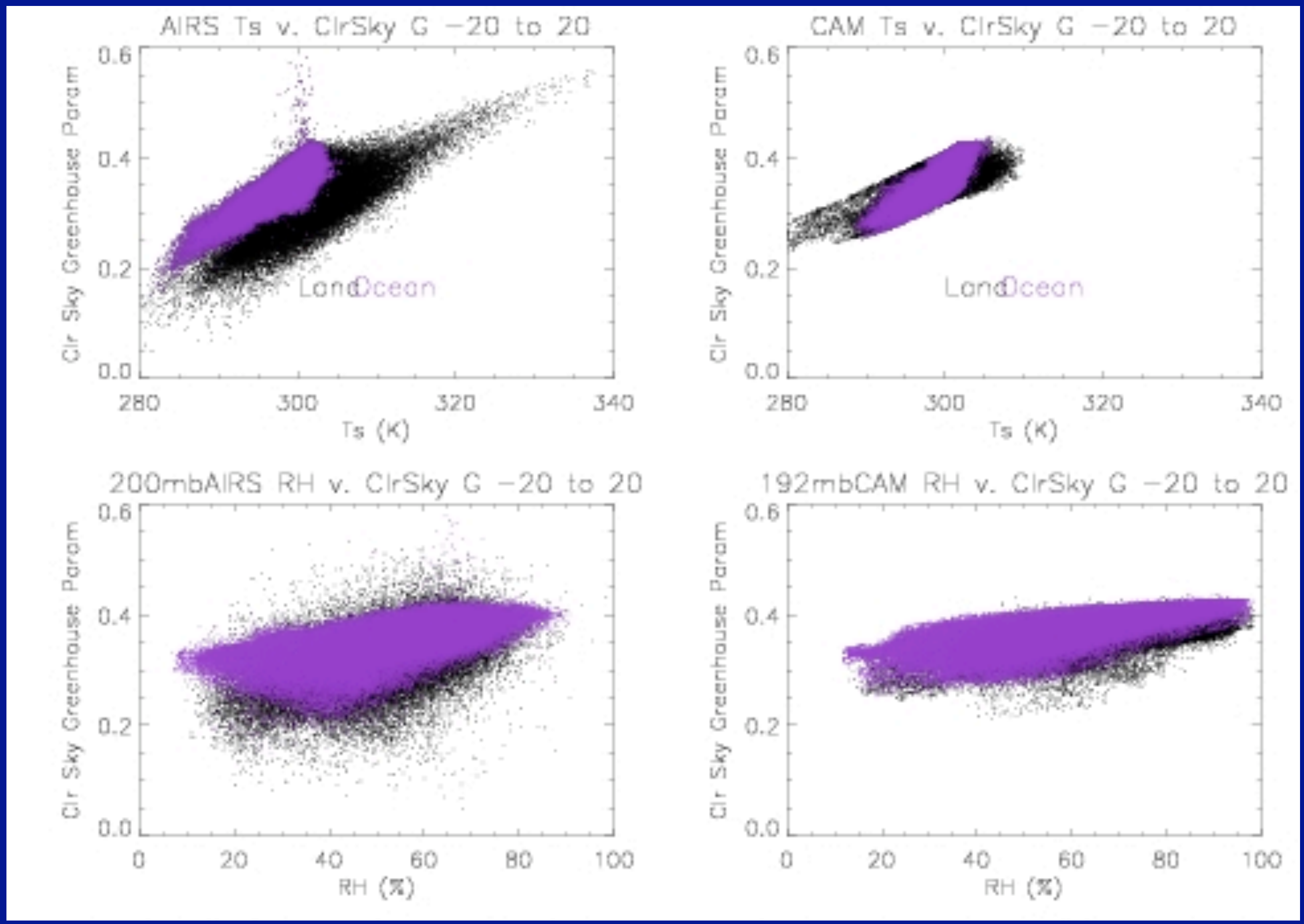
# GHP Monthly: Each point

Normalized for Ts: $G = (\sigma T_s^4 - OLR)/\ \sigma T_s^4$

Observations Model

GHP v. Ts

GHP v. RH




GHP also increases with H2O (specific humidity)

# Summary (1)

- AIRS UTH:
  - Good vertical structure (RH ‘bimodal’ in vertical)
  - New insights into variability, from daily->annual
- GCM/CAM:
  - Reproduces climatology, some biases
  - Too moist in subtropics (some radiative impacts)
  - Variability not well reproduced

# Summary (2)

- Supersaturation is important in UT
  - Common in UT
  - Looking for anthropogenic effects on clouds
- AIRS can provide insight on climate forcings
  - Greenhouse effect appears to increase with SST
  - Water vapor feedback positive: but not as positive as constant RH would assume
  - Climate model appears to reproduce these relationships on a monthly basis (RH more constant than observed)